

Instructions Excel tool for the Extended Smooth Pathway Model (ESPM)

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The latest version of the Excel tool can be downloaded at [zenodo](#).

Overview tools based on the ESPM approach at <https://www.climate-calculator.info>.

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1 Basic idea behind the ESPM¹

- **National budgets:** A predefined **global CO2 budget** 2020 – 2100 is **distributed** to **countries**. The tool offers the use of a weighted distribution key that includes the 'population' and the 'emissions' in a base year (here: 2019). In this way, current reality and climate justice can be mapped.
- **National paths:** The tool offers the Regensburg Model Scenario Types RM 1 - 6 to derive plausible **national paths** from a national budget. This scenario types cover the range of plausible possibilities well.

2 Brief introduction to the tool for the ESPM

With this tool you can determine national budgets and plausible national emission paths from this budget.

For deriving **national paths**, the tool offers the Regensburg Model Scenario Types **RM 1 - 6**. There differ in particular in terms of different assumptions on the trajectory of annual reduction rates resp. reduction amount.

In the **sheet 'base data'** you can set the basic conditions such as the budgets which are to be met, and the minimum value of national annual emissions (potential for net negative emissions). To determine the national budget a simple weighting model is offered.

In the **sheet 'reference values'**, you can select a country from the drop-down list, to get an impression of which challenges the chosen country is confronted with and can then compare these with the offers this country has submitted so far or plans to submit (NDCs).

In the **sheet 'output countries'** you can create a list of all countries in the world, which gives the **national budgets** 2020 - 2100 for a given weighting of the population and a given global budget and **reference values** for the **six largest emitters**.

In the **sheet 'fig big six'** you can create figures for the six largest emitters (emission paths and targets for 2030 depending on population weighting).

If you change the input data (for which the yellow shaded cells are intended) or select a different country, you must always run the **macro** in the **"goal seek" sheet** to adjust the free parameters in the scenarios via a target value search in order to comply with the national budget 2020 - 2100, which is specified in the "base data" sheet.

The macros in the "output countries" and "fig big six" sheets already contain the target value search.

¹ For a further description of the ESPM, see

- published papers in the "References" (p. 9) and
- a brief description [here](#).

3 Entries in the sheet ‘base data’

I. a) Global CO2 budget 2020 – 2100

Input global CO2 budget 2020 - 2100 based for example on the Sixth Assessment Report of the IPCC 2021 [[see](#) separate paper for download in the sheet ‘base data’; (Wolfsteiner, 2023)].

I. c) Global CO2 budget 2020 – 2100 without LUC and ISA

Since, among other things, it is difficult to find figures for individual countries for CO2 emissions caused by land use changes (LUC), these emissions are not included here and must therefore be deducted.

Enter the LUC budget 2020 – 2100 in Gt. A negative value means that in sum the net negative LUC emissions would be higher than the net positive emissions in this period [[see](#) separate paper on this topic: (Wolfsteiner & Wittmann, 2023b)].

Emissions from international shipping and aviation (ISA) also have to be deducted, since attribution to countries is also difficult. The current share of global ISA emissions is given as information.

LUC and ISA are also not included in the national data used (see hidden sheet "EDGAR").

The result is the global budget, which can be distributed across countries in this tool for the period 2020 - 2100.

II. National CO2 budget 2020 – 2100

The national budget used here results from the application of a weighted distribution key to the global budget 2020 - 2100. The distribution key includes: the country's share of the global population and global emissions in 2019:

$$B^i = \left(C * \frac{P_{BY}^i}{P_{BY}} + (1 - C) * \frac{E_{BY}^i}{E_{BY}} \right) * B$$

where

B resp. B^i global budget resp. budget of country i ; budget period: 2020 - 2100

E_{BY} resp. E_{BY}^i global emissions resp. emissions of country i in the base year

P_{BY} resp. P_{BY}^i global population resp. population of country i in the base year

C weighting of population

You can specify the weighting of the population (C) here.

You can also enter a freely calculated national budget 2020 - 2100. In this case, please make sure that the national budget does not include LUC and ISA.

III. National minimum emissions

Here you can specify which minimum the national paths can achieve in 2100 (E_{min}). If you specify a negative value, this means net negative emissions. This sets the potential for net negative emissions.

The specification is made by entering a percentage that will be applied to national emissions in 2019 of the chosen country [[see](#) separate paper on this topic: (Wolfsteiner & Wittmann, 2023b)].

4 Determination of national emission paths

4.1 Entries in the sheet 'goal seek'

- RM 2 – 5: rates of change for 2020 (RR_{20}).
The actual RR_{20} cannot be used because of the temporary corona effect. Instead, a value should be used that would probably have been set without corona. The actual change rate in 2019 of the chosen country is given in this sheet as an orientation.
- RM 1 and RM 2 – 5: threshold values (TVs).
In scenarios RM 1 - 5, a constant reduction amount is applied from this threshold values for the transition to **net negative emissions**.

4.2 Where and how the national paths are determined

The **paths** are **calculated** in the sheet '**RM**'.

The tool offers the Regensburg Model Scenario Types RM 1 - 6 for the determination of national paths (see Chapter 4.4).

When using scenario types RM 1 - 6, the paths are essentially determined indirectly by determining the **annual rates of change** (RM 1 - 5) or the **annual constant reduction amount** (RM-6). From the specified threshold value (TV), a constant reduction amount is used until the emissions reach the predefined minimum value (E_{min}).

In the sheet '**goal seek**' the free parameter of the respective scenario is determined for each scenario type using an iterative solution method so that the budget is adhered to. The '**goal seek**' **macro** in this sheet uses the target value search integrated in Excel for this purpose (see Chapter 4.6.2).

4.3 Phases determining paths

This usually leads to the following **three phases** for determining the paths:

1. Application of the annual reduction rates (RM 1 - 5) or the annual reduction amount (RM-6).
2. Annual emissions less than or equal to TV : The last annual absolute reduction is continued.
3. Minimum for the annual emissions (E_{min}) that you specify in the sheet 'base data' will be applied until 2100.

These three phases can be found in the formula for the annual emissions in the individual scenario types in the sheet 'RM'.

4.4 RM Scenario Types 1 – 6

For a comprehensive mathematical description, we refer to our paper 'Mathematical Description of the Regensburg Model Scenario Types RM 1 – 6 (Wolfsteiner & Wittmann, 2023a); published on [zenodo](#). [Here](#) is a further brief description of the RM Scenario Types.

4.5 Actual emissions after the base year 2019

As soon as they are available, the actual emissions are filled in the sheet 'RM'. Thus, the free parameter is only determined for the remaining budget period.

4.6 Macros in the sheet 'goal seek'

4.6.1 Macro security

Please use Microsoft's instructions to allow macros if they have been blocked.

In most cases, you can unblock macros by changing the properties of the file as follows:

- Open Windows File Explorer and go to the folder where you saved the file.
- Right-click on the file and select Properties from the context menu.
- At the bottom of the General tab, select the Unlock check box and then OK.

If you do not want to use the built-in macros, you can save the file as an xlsx file. This will remove all macros.

We have published the code of the most important macro 'goal seek' here:

<https://doi.org/10.5281/zenodo.7494168>

This gives you the option of integrating the macro into your Excel file yourself.

4.6.2 Macro 'goal seek'

The macro 'goal seek' tries to determine the free parameter in the scenario (row 12 or 13) so that the national budget (row 16) is adhered to (► row 15 = row 16). The macro also ensures that the constraints for the free parameter are met.

If this does not succeed at first go, the macro tries to find a solution with a different rate of change for 2020 in the scenario types RM 2 - 5. The initial value you specify is changed by a maximum of 2.5 percentage points in both directions in 0.01 steps. The start value you specified will therefore be changed. If a solution cannot be found either, the macro will inform you and advise you to change the start value for 2020 more significantly.

In the RM-1 scenario, the macro increases the threshold value (TV) if necessary to find a solution.

The macro also tries in scenario RM-1 that the minimum value (E_{min}) specified in the sheet 'base data' is reached (► row 18 = row 19). If this does not succeed straight away, the macro increases the threshold value (TV) in the RM-1. If E_{min} can still not be reached, the original TV will be reset.

Macro 'copy':

If you want to use the same start change rate 2020 in scenarios RM 2 - 5, you can enter this at the intended position and copy it with this macro in RM 2 - 5.

4.6.3 Macros finding appropriate framework data

The following macros make it possible to set emission targets and to search for the appropriate global budget, potential for net negative emissions or weighting of the population.

Before these macros can be executed, the normal target value search for the scenario types RM 2 - 6 must have been carried out successfully.

Set emissions target for 2030:

Macro 'finding budget'

With this macro you can set the emissions **target** for a certain scenario type for **2030** compared to 1990 and search for the **appropriate global budget**. The 2030 emissions target to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition for 2030 in its NDC than would be necessary with the given framework data. This shows which global budget NDC for 2030 corresponds to with otherwise the same framework data.

The scenario types RM-2, RM-4 and RM-6 are particularly suitable for this analysis. The scenario types RM-3 and RM-5 are less suitable if a country is not very ambitious when it comes to the 2030 emissions target, since in these scenario types a relatively rapid increase in the annual reduction rates is implemented right from the start. This characteristic does not come into play due to the less ambitious 2030 target. However, the later increase in the reduction rates is only possible to a limited extent with these scenario types. Therefore, a less ambitious target for 2030 requires a relatively high budget for these scenario types.

Macro ‘finding NNE’

With this macro you can set the emissions **target** for a certain scenario type for **2030** compared to 1990 and search for the **appropriate** potential for **net negative emissions**. The 2030 emissions target to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition for 2030 in its NDC than would be necessary with the given framework data. This shows which potential for net negative emissions correspond to with otherwise the same framework data.

The scenario types RM-2, RM-4 and RM-6 are particularly suitable for this analysis. The scenario types RM-3 and RM-5 are less suitable if a country is not very ambitious when it comes to the 2030 emissions target, since in these scenario types a relatively rapid increase in the annual reduction rates is implemented right from the start. This characteristic does not come into play due to the less ambitious 2030 target. However, the later increase in the reduction rates is only possible to a limited extent with these scenario types. Therefore, a less ambitious target for 2030 requires a relatively high potential for net negative emissions for these scenario types, or no suitable potential for net negative emissions can be found.

Macro ‘finding weighting population’

With this macro you can set the emissions **target** for a certain scenario type for **2030** compared to 1990 and search for the **appropriate weighting of population**. The 2030 emissions target to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition for 2030 in its NDC than would be necessary with the given framework data. This shows which weighting of population correspond to with otherwise the same framework data.

Specify year emission neutrality:

Macro ‘finding budget’

With this macro you can set the **year of emissions neutrality** for a certain scenario type and search for the **appropriate** global **budget**. The year of emissions neutrality to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition in its NDC than would be necessary with the given framework data. This shows which global budget NDC corresponds to with otherwise the same framework data.

Macro ‘finding NNE’

With this macro you can set the **year of emissions neutrality** for a certain scenario type and search for the **appropriate** potential for **net negative emissions**. The year of emissions neutrality to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition in its NDC than would be necessary with the given framework data. This shows which global budget NDC corresponds to with otherwise the same framework data.

Macro 'finding weighting population'

With this macro you can set the **year of emissions neutrality** for a certain scenario type and search for the **appropriate weighting of population**. The year of emissions neutrality to be specified must be less ambitious than the solution already found.

The use of this macro is particularly useful if a country specifies a lower level of ambition in its NDC than would be necessary with the given framework data. This shows which global budget NDC corresponds to with otherwise the same framework data.

5 Reference values for every country in the world

In the sheet 'reference values', any country in the world may be chosen from the drop-down list.

Above this sheet you will see whether the target value search must be carried out in the sheet 'goal seek'.

The 'reference values' sheet mainly shows the change in a country's emissions from different target years to reference years as reference values.

The national budgets, the sum of the national net negative emissions (overshoot) and the year of emissions neutrality are also reported.

In the sheet 'goal seek', we also offer macros (see Chapter 4.6.3) with which an **emissions target for 2030** or the **year of emissions neutrality** can be specified and the **appropriate global budget, potential for net negative emissions** or **weighting of the population** can be found.

6 Reference values for the six largest emitters

In the sheet 'output countries' you can create a list of all countries in the world, which gives the **national budgets 2020 - 2100** for a given weighting of the population and given global budget and **reference values** for the **largest emitters**. These macros also perform the target value search ('goal seek'). The actual value from 2019 is used as the starting rate of change in 2020 in the scenario types RM-3, RM-4 and RM-5.

7 Figures for the six largest emitters

In the 'fig big six' sheet, you can create the following figures for the six largest emitters with macros:

- Population weighting and resulting emission targets for 2030 compared to 2019 based on the scenario type RM-6.
- Emission paths of the six largest emitters based on the scenario types RM-3, RM4 or RM-6.

The following framework data can be specified there:

- Global budget
- Weighting population
- LUC budget
- Potential for net negative emissions (NNE)

Use the macros in this sheet to update the figures. These macros also perform the target value search ('goal seek').

The actual value from 2019 is used as the starting rate of change in 2020 in the scenario types RM-3 and RM-4.

8 References

Sargl, M., Wiegand, D., Wittmann, G. & Wolfsteiner, A., 2021. Berechnung Paris-kompatibler Emissionsziele für die sechs größten Emittenten mit dem ESPM. *Zeitschrift für Umweltpolitik & Umweltrecht*, Issue 3/2021, pp. 269 - 286.

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Wolfsteiner, A. & Wittmann, G., 2023b. *Treatment of the topics LUC and net negative emissions in the RM and ESPM tools*. [Online]
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